Quality Assurance Project Plan:

FORECASTING WATER QUALITY AND QUANTITY HAZARDS USING SPATIALLY DISTRIBUTED WATERSHED MODELS AND BIOPHYSICAL DATA

QAPP Approval/Concurrence

The attached Quality Assurance Project Plan for the project entitled "Forecasting Water Quality and Quantity Hazards Using Spatially Distributed Watershed Models and Biophysical Data" is recommended for approval and commits the participants to follow the elements described within.

Approvals

Name	Title	Affiliation	Signature, Date
William G. Kepner	Principal Investigator	LEB	[signature] 3/28/07
David C. Goodrich	Principal Investigator	USDA/ ARS	[signature] 3/28/07
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Quality Assurance Project Plan:

Forecasting Water Quality and Quantity Hazards Using Spatially Distributed Watershed Models and Biophysical Data

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The following Quality Assurance Project Plan (QAPP) has been developed in support of an interagency agreement (Project DW12922094010; Forecasting Water Quality and Quantity Hazards Using Spatially Distributed Watershed Models and Biophysical Data) between the U.S. Environmental Protection Agency, Environmental Sciences Division, Landscape Ecology Branch, Las Vegas, NV and the USDA Agricultural Research Service, Southwest Watershed Research Center, Tucson, AZ. This is a Category 3 QAPP that is intended to also adhere to the EPA National Geospatial Data Policy (USEPA 2005) in regard to laboratory procedures regarding the planning, collecting, acquiring, processing, documenting, storing, accessing, maintaining, and retiring of geospatial data. This is particularly important both in regard to the environmental issues and research that are of joint concern between EPA and ARS and for the fact that agency policy requires EPA to build information partnerships across multiple levels of government, including the public and private sectors.

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1 Introduction

Water resources and ecosystems around the globe are coming under increasing stress due to both natural and human-induced factors resulting in increased water use, land use changes including urbanization, etc. (Sivapalan et al. 2003). Recent research suggests that a warmer climate might increase the frequency of extreme events, i.e. heavy precipitation and droughts (Karl et al. 1995; Tsonis 1996). This change includes an increase of the amount of randomness in the system, which in turn leads to a decrease in the predictability of the system (Tsonis 2004). Both flood risk and the occurrence of drought therefore appear to be increasing and regions where observational data are sparse tend to be most vulnerable. This is particular true for many less developed countries where floods and droughts consistently result in substantial loss of life. But countries in the developed world are also increasingly affected; for example, the 1993 flood in the Midwest USA showed recurrence intervals between 100 and 500 years in some locations along the Mississippi and Missouri Rivers (Kundzewics and Kaczmarek 2000).

Sustainable management policies are required to respond to these trends. Among the sources of information available to decision-makers and policy-makers are predictive models capable of simulating the behavior of the hydrological systems over a broad range of space and time scales, and (potential) climates. These predictions are inherently uncertain as a result of incomplete knowledge of the system, variability in system properties, randomness in the system stresses, measurement and sampling errors, simulation, and actual scales of the system. These uncertainties are manifested in a hydrologic model as uncertainty in model conceptualization, model parameters, and model scenarios. Assessing the impact of parameter uncertainty on model predictions is accepted in policy (EPA 1997) and is fairly common practice. However, understanding scenario uncertainty and communicating it to policy-makers and stakeholders in an appropriate way represents a particular area that deserves extensive research efforts (Liu et al. 2007). Geographic Information Systems (GIS) have been widely used to facilitate the parameterization of hydrologic models and visualization of model results through the development of GIS-based model interfaces (e.g. Ogden et al. 2001; Miller et al. 2007). Land-cover/use grids are a principal input to watershed hydrologic models and the primary means of incorporating anthropogenic impacts into distributed hydrologic assessments. Alternative future land-cover/use grids thus provide a means of incorporating projected growth and development into hydrologic assessments for the purpose of exploring potential environmental impacts associated with future scenarios (Semmens et al. 2006). Many simulation models have been used to test the dynamics of future scenarios; for instance, to assess the impact of future climate scenarios (e.g. Leavesley, 1994; Jones et al. 2002; and Fowler and Kilsby 2007), and future land use scenarios (e.g. Kepner et al. 2004; Semmens et al. 2006; Kepner et al. 2007) on water quantity and water quality. This technique holds a great promise as a means of providing decision support for planning efforts, but a significant concern is the lack of available information on the uncertainty and appropriate use of physically based hydrologic models in a forecasting mode.

In August 2006, the United States Environmental Agency (EPA), National Exposure Research Laboratory (NERL), Landscape Science Program and the United States Department of Agriculture, Agricultural Research Service (ARS) entered into an Interagency Agreement entitled “Forecasting Water Quality and Quantity Hazards Using Spatially Distributed Watershed Models and Biophysical Data”. The goals of this interagency agreement include: 1) prioritization of forecasting products suitable to incorporate into watershed and water quality modeling; 2) identification of the best strategies to incorporate near-term forecast into watershed and water quality models; 3) improve the capability of the Automated Geospatial Watershed Assessment (AGWA) tool and the KINEROS2 watershed model to conduct near-term and longer-term forecast, and 4) pilot test a prototype web-based water quality and quantity forecast capability.

An important project task within the interagency agreement is the incorporation of OPUS' soil water balance and plant growth components into KINEROS2 to create a new model, based on the one-dimensional Richards' equation of unsaturated flow and the kinematic wave approximation for overland flow and channel flow, suitable for continuous watershed and water quality modeling. The model will be tested and validated following guidelines described in this Quality Assurance Quality Project Plan.

In addition, a second main task within the interagency agreement is the development, testing and validation of the DotAGWA web application. DotAGWA project is a continuation or extension of the AGWA application. DotAGWA is being constructed to make most of the features and functions in AGWA 2.0, the ArcGIS version of AGWA hereafter referred to as AGWA2, available through a web-based interface. DotAGWA will be the web-based version of AGWA. DotAGWA will be automated to the greatest extent possible to make it relatively simple to use, as well as easier to develop in the more complex web environment. As such, functionality will be selectively implemented to maximize versatility and model performance, but at the expense of user interaction with data, models, and look-up tables.

Developing efficient and reliable software and applying such tools in watershed modeling requires a number of steps, each of which should be taken conscientiously and reviewed carefully. Taking a systematic, well-defined and controlled approach to all steps of the model (software) development and application process is essential for successful implementation of the model. Quality Assurance (QA) provides the mechanisms and framework to ensure that decisions are based on the best available data and analyses.

The following sections provide background information on QA and define its role in watershed modeling. They present a functional and practical methodology, written from the perspective of the model user in need of technical information on which to base decisions. An important part of quality assurance is code testing and performance evaluation.

1.1 Purpose

The purpose of this Quality Assurance Project Plan is to document the procedures that will be followed to ensure that the KINEROS-OPUS model, DotAGWA interface, and AGWA2 updates conform to design objectives and specifications, and that they correctly perform the incorporated functions. These procedures include parameterization of the hydrologic models, the application of coding standards and practices for the development of the models, testing of their functional design, and evaluation of their performance characteristics, and documentation testing. This will be accomplished through extensive testing of a set of examples with known data sets. In addition, the focus of this IAG is on the forecasting of hydrologic impacts associated with landscape change/management. As such, another subset of IAG tasks involves the development and integration of tools into AGWA2/DotAGWA that permit consideration of potential future climatic conditions. This plan includes a description of how the verification of new tools will be undertaken to ensure that they are functioning reliably and as intended.

1.2 Report Organization

The structure of this document reflects EPA's quality assurance guidelines for modeling development and application projects (EPA 1991). This report begins with section 2 providing background information on quality assurance in hydrologic modeling. Section 3 describes the project organization and identifies technical personnel involved in the project. Section 4 describes briefly the main components of each hydrologic model. Section 5 deals with data source and input/output quality assurance. This section includes quality assurance and quality control for hydrologic modeling. Section 6 describes software development and code testing. Finally, section 7 describes documentation to be generated.

2 Quality Assurance

2.1 Quality Assurance Definitions

Quality assurance in hydrologic modeling is the procedural and operational framework put in place by the organization managing the modeling study to ensure adequate execution of all project tasks included in the study, and to ensure that all modeling-based analysis is verifiable and defensible (Taylor 1985).

The two major elements of quality assurance are quality control and quality assessment. Quality control refers to the procedures that ensure the quality of the final product. These procedures include the use of appropriate methodology in developing and applying computer simulation codes, adequate verification and validation procedures, and proper usage of the selected methods and code. Quality assessment is applied to monitor the quality control procedures and to evaluate the quality of the studies (van der Heijde 1987).

2.2 Model Development Process

Before a model or software product is used as an evaluation tool, its credibility must be established through systematic testing of the model's accuracy and evaluation of the model's performance characteristics. Of the major approaches, the evaluation or review process is rather qualitative in nature, while code testing results can be expressed using quantitative performance measures. Performance characteristics may be expressed in terms of reliability, efficiency of coded algorithms, and resources for model setup. Performance characteristics need to be determined for the full range of parameters and stresses that the code is designed to simulate. It is also important to test the code to determine the consequences if the code is used beyond its original design criteria, or beyond the range of applications for which it has already been tested. Through extensive and systematic code testing and model evaluation, confidence in the applicability of the code will increase.

Code testing is aimed at detecting programming errors, testing embedded algorithms, and evaluating the operational characteristics of the code through its execution of carefully selected examples, test problems, and test data sets. It is important to distinguish between code testing and model testing. Code testing is limited to establishing the correctness of the computer code with respect to the criteria and requirements for which it is designed. Model testing is more inclusive than code testing, as it represents the final step in determining the validity of the quantitative relationships derived for the real-world prototype system the model is designed to simulate.

In this report, code validation is defined as the process of determining how well the KINEROS-OPUS and DotAGWA code's theoretical foundation and computer implementation describe actual system behavior in terms of the degree of correlation between calculated and independently observed responses of the reference hydrologic system for which the code has been developed.

In this report, code verification is defined as the process of demonstrating the consistency, completeness and accuracy of the KINEROS-OPUS and DotAGWA codes with respect to their design criteria by evaluating the functionality and operational characteristics of the codes.

3 Project Organization

The USDA/ARS/SWRC will be responsible for conducting model and model-interface development activities associated with this QAPP. The key quality assurance (QA) and technical personnel that will be involved in these efforts, their contact information, and their responsibilities are provided in Table 1 and Figure 1.

Table 1. Key personnel, including their contact information and project responsibilities.

Mr. William G. Kepner 702-798-2193 kepner.william@epa.gov	U.S. EPA Project Officer and Principal Investigator
Mr. George M. Brilis 702-798-3128 brilis.george@epa.gov	U.S. EPA QA Manager. Mr. Brilis will ensure that the QAPP meets the criteria as outlined in the "QAPP Requirements for Applied Research Projects" for the subject project.
Dr. Darius J. Semmens 702-798-2267 semmens.darius@epa.gov	U.S. EPA Investigator. Dr. Semmens will oversee the project to see that it meets EPA modeling needs.
Dr. David C. Goodrich 520-670-6381 x144 dgoodrich@tucson.ars.ag.gov	USDA-ARS Project Officer and Principal Investigator. Dr. Goodrich will oversee the project and be the primary contact between U.S. EPA and USDA-ARS.
Dr. Mariano Hernandez 520-670-6381 x147 mhernandez@tucson.ars.ag.gov	USDA-ARS Investigator. Dr. Hernandez will oversee the design and execution of testing, documentation, QA/QC control and reporting.
Mr. Averill Cate 520-670-6381 x162 acate@tucson.ars.ag.gov	USDA-ARS Investigator. Mr. Cate will be the primary developer of DotAGWA.
Mr. Carl Unkrich 520-670-6381 cunkrich@tucson.ars.ag.gov	USDA-ARS Investigator. Mr. Unkrich will be the primary developer of KINEROS2-OPUS.
Mr. I. Shea Burns 520-670-6381 x162 iburns@tucson.ars.ag.gov	USDA-ARS Investigator. Mr. Burns was the primary developer of AGWA2 and will be responsible for developing its new tools and functionality.

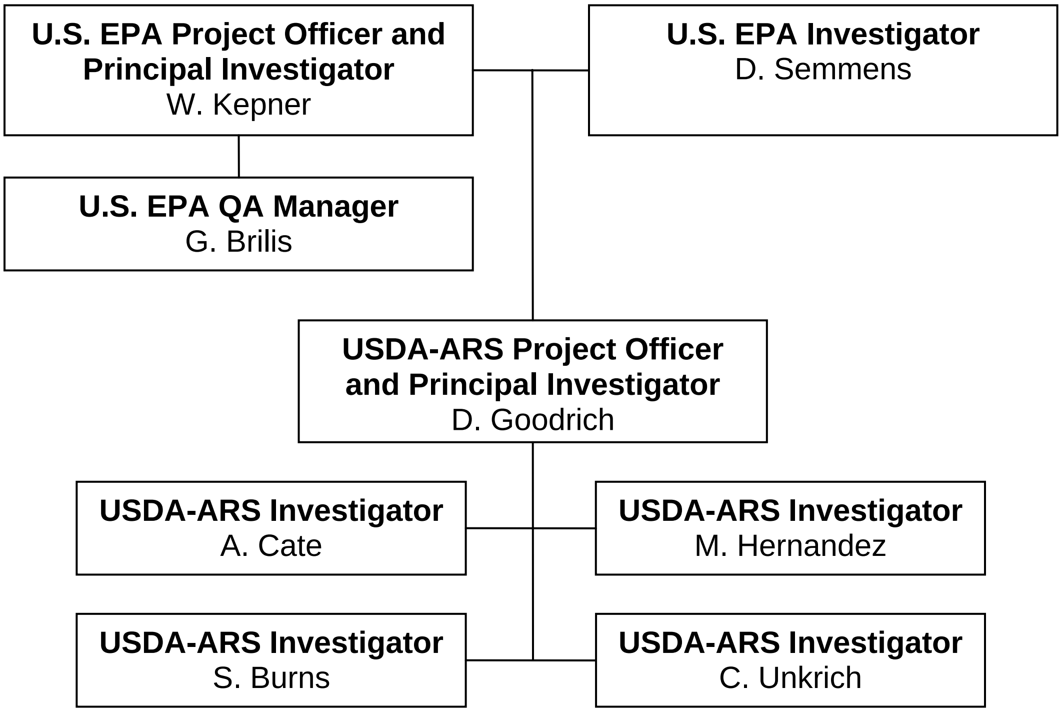

Figure 1. Key personnel and project organization.

4 Models Description

4.1 KINEROS2

KINEROS2 is an event-oriented, physically based model describing the processes of interception, infiltration, surface runoff, and erosion from small agricultural and urban watersheds (Smith et al. 1995). In this model, watersheds are represented by discretising contributing areas into a cascade of one-dimensional overland flow and channel elements using topographic information. The infiltration component is based on the simplification of the Richard’s equation posed by (Smith and Parlange 1978).

4.2 OPUS

OPUS is a deterministic agro-ecosystem model with the following basic components: evapotranspiration, infiltration, surface runoff and erosion, unsaturated flow in the soil profile, crop growth, nitrogen, carbon, phosphorous and pesticides (Smith 1992a). When developing OPUS, the design goals were to: 1) create a model suitable to use without calibration; 2) maintain a balance regarding the complexity of different model components and process detail; and create a model that is easy to operate since it should be useful for both research and management applications (Smith 1992b).

4.3 AGWA2

An ArcGIS-based version of the Automated Geospatial Watershed Assessment tool, AGWA2, was developed under the EPA/ARS IAG “Landscape Indicator Interface with Hydrologic and Ecologic Models”, Amendment 4, DW12939409. The procedures followed to ensure that AGWA2 conforms to the design objectives and specifications, and that it correctly performs the incorporated function were reported in the document entitled “Quality Assurance and Quality Control in the Development and Application of the Automated Geospatial Watershed Assessment (AGWA) Tool by Hernandez et al. 2002 (EPA/600/R-02/046 and ARS/137460).

4.4 DotAGWA

The AGWA2/DotAGWA project is a continuation or extension of the AGWA application. AGWA2 is the conversion of AGWA 1.x, which is an ArcView-based application, to an ArcGIS-based application. DotAGWA is designed and constructed to make most of the features and functions in AGWA2 available through a web-based interface, as well as to utilize the same software code for performing GIS-related tasks and analyses that are shared between the two applications. DotAGWA will be the web-based version of AGWA (Cate et al., 2005).

5 Data Source/Quality/Input-Output

5.1 Digital Elevation Model (DEM) Data

The two most important aspects in the selection of a DEM for hydrologic modeling are the quality and resolution of the DEM data. Quality refers to the accuracy of the elevation data, and resolution refers to the horizontal grid spacing and vertical elevation increment. Quality and resolution must be consistent with the scale and model of the physical process under consideration and with the study objectives. The U.S. Geological Survey, Earth Science Information Center, offers a variety of digital elevation data products. These include the 7.5-minute grid DEM data, 1 degree grid DEM data, regular angular 30-minute grid DEM data, and contour DLGs corresponding to maps of various scales. The USGS 7.5-minute DEM data have a grid spacing of 30 by 30 meters, are cast on Universal Transverse Mercator (UTM) projection, and are produced from contour overlays or from automated or manual scanning of National Aerial Photography Program stereophotographies. Elevation values are provided in either feet or meters. Digital elevation data is available for download at http://seamless.usgs.gov/website/seamless/index.asp

5.2 Soil Data Bases

The main source for soil information to test the KINEROS2–OPUS and DotAGWA computer applications is from the USDA Natural Resources Conservation Service (NRCS) and Food and Agriculture Organization (FAO). The two NRCS soil geographic data bases are the Soil Survey Geographic (SSURGO) and the State Soil Geographic (STATSGO). The SSURGO data base provides the most detailed level of information and was designed primarily for farm and ranch, land/owner user, township, county, or parish natural resource planning and management. The STATSGO data base was designed primarily for regional, multi-state, river basin, State, and multi-county resource planning, management, and monitoring. The FAO data base provides the most detailed, globally consistent soil data. Soil maps for the STATSGO are available for download at http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/index.html. Soil maps for SSURGO are available for download at http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/. And soil maps for FAO are available for download at http://daac.gsfc.nasa.gov/interdisc/readmes/soils.shtml#100.

5.3 Land Use/Cover Data Sets

The derivation of hydrologic parameter values affected by land cover use is derived from The North American Landscape Characterization (NALC) classification and the Multi-Resolution Land Characteristics (MRLC). The NALC data consists of Landsat Multi-Spectral Scanner (MSS) time series triplicates that were acquired in 1973, 1986, and 1991(+/- one year). Complete coverage exists for the United Sates and Mexico for 60 by 60 meter pixels in a UTM projection. On average, a NALC triplicate consists of one scene from 1990s and 1980s, and two from the 1970s for each path/row. The NALC data sets are available for download at http://edcsns17.cr.usgs.gov/helpdocs/V0guide/campaign_documents/nalc_proj_camp.html. The MRLC data is a collection of terrain-corrected Landsat 7 Enhanced Thematic Mapper Plus and Landsat 5 Thematic Mapper (TM) scenes that have been acquired by the MRLC Consortium. The MRLC 2001 data cover the United Sates, including Alaska and Hawaii. Most of the images are of high quality, and cloud cover is generally less than ten percent. The data includes a 30-meter Digital Elevation Model for all scenes that do not include the Canadian or Mexican Border. Both data sets are available for download at http://mrlc.gov/index.

In addition, derivation of hydrologic parameter values will be carried out employing land cover maps generated by the Southwest Regional Gap Analysis Project, which is a multi-institutional cooperative effort coordinated by the U. S. Geological Survey’s National Gap Analysis Program. The primary objective of this project is to use a coordinated mapping approach to create detailed, seamless maps of land cover, habitat for native terrestrial vertebrate species, land stewardship, and management status for the five-state region encompassing Arizona, Colorado, Nevada, New Mexico, and Utah. The region was segmented into mapping zones, attempting to divide the area into homogeneous landscape units. The zones are based on expert knowledge, elevational gradients, and satellite imagery interpretation. 1999-2001 Landsat 7 Enhanced Thematic Mapper Plus imagery and sophisticated analytical procedures were used to classify the vegetation. Land cover was mapped to a 2-5 ha resolution. Land cover mapping adhered to Federal Geographic Data Committee standards and used the National Vegetation Classification System (NVCS). NVCS is a standardized classification system that provides a hierarchical framework for describing vegetation. Land cover was mapped using a combination of ecological systems and alliance level classification and included exotic and semi-natural types. Accuracy assessment was conducted to provide needed information to end-users. Digital products are available for download at http://earth.gis.usu.edu/swgap/landcover.html

5.4 Precipitation Data for Hydrologic Modeling

Confidence in the hydrologic modeling effort depends, to a large extent, on the availability of high quality rainfall and runoff data for model calibration and verification.

Many sources of rain gauge data are available. However, the likelihood of obtaining rain gauge data for a particular watershed is small because of the sparse nature of the national rain gauge network. Rainfall data are archived by the NOAA National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html).

Relevant available precipitation data from NCDC include: daily parameters such as maximum/minimum temperature, precipitation, and snowfall/snow depth. Some stations have additional data such as evaporation and soil temperature. Hourly rainfall rates are recorded at the National Weather Service meteorological stations. These stations are sparsely located around the U. S. The period of record for these data is quite variable, with few stations installed before 1970. The NCDC is very efficient at archiving available precipitation data sources, and performing quality control on the data (American Society of Civil Engineers 1999). Unfortunately, the precipitation data from the NCDC is not available free on-line.

In Walnut Gulch, a long-term experimental watershed near Tombstone, AZ, rainfall observations from more than eighty gages are available. These are standard weighing type gages that record the cumulative depth of precipitation continuously as a line trace on a revolving chart driven by an analog clock. The chart completes one revolution in 24 hours and remains in place for seven days before it is replaced with a fresh chart. These charts are manually checked and inferred for starting and ending times of rainfall events. Weekly rain gages (one chart revolution per 7 days) are also used to infer storm start times.

5.5 Water Quality Data

Water quality data for testing the KINEROS2-OPUS model will be retrieved from EPA's computerized environmental data system STORET (STOrage and RETrieval) (http://www.epa.gov/storet/), and from the USGS National Water-Quality Assessment Data Warehouse (http://water.usgs.gov/nawqa/data). Both systems are web-enabled and available to the public.

5.6 Future Scenarios

Decision-makers, managers, scientists demand tools that can help with forecasting future land cover and climatic conditions under different circumstances; unfortunately, future land-use/cover and climatic conditions can never be known with certitude. The goal of regional planning efforts is to explore desired stakeholder outcomes, and it is assumed that policy can be used to shape the future change and guide it towards a particular outcome. As a result, climate conditions are the primary unknown in projecting future hydrologic response.

Research addressed within this interagency agreement is focused on determining how hydrologic and environmental impacts can be assessed relative to the cumulative effect of past, proposed, or reasonably foreseeable future actions and whether urban growth patterns can be managed to minimize hydrologic and environmental impacts. A wide range of future and historical scenarios will be used with KINEROS2-OPUS and DotAGWA models.

A range of plausible future climatic conditions and events will be estimated based on records of historical events and scenario-based model projections with the Climate Assessment Tool. The U.S. Environmental Protection Agency's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) is a multipurpose environmental analysis system designed for use by regional, state, and local agencies (EPA 2001). The most recent Version 4 release of BASINS includes the Climate Assessment Tool that provides new capabilities for assessing impacts and conducting systematic sensitivity analyses for specific hydrologic and water quality endpoints using BASINS models; the AGWA tool is incorporated into the BASINS product. Specific capabilities of the Climatic Assessment Tool include an ability to create and run new meteorological time series either by modifying historical data, or using CLIGEN (Nicks et al. 1995), a stochastic weather generator which produces daily estimates of precipitation, temperature, dewpoint, wind, and solar radiation for a single geographic point, using monthly parameters derived from historic measurements.

6 Software Development and Code Testing

In this section the process of developing and testing the main components of KINEROS2-OPUS and DotAGWA are described.

6.1 KINEROS2-OPUS

The code testing for KINEROS2-OPUS will demonstrate that the model will run successfully and produce coherent ouput given reasonable ranges of parameters and input data. The code will also be tested for its ability to trap extreme or missing values and avoid unprogrammed termination. Since the model for soil water movement in OPUS is numerically demanding compared to the infiltration model in KINEROS2, the code will be benchmarked relative to CPU-time requirements for different levels of spatial complexity. It will be verified that the individual submodels within the combined model will reproduce the behavior of components from the original models under appropriate circumstances. This will include comparisons of rainfall-runoff routing over impervious surfaces (KINEROS2) and soil water movement under unponded conditions, with vertical movement of nitrogen and phosphorous, carbon cycling, evapotranspiration and changes in plant biomass (OPUS). For interactions between submodels that cannot be isolated, such as between the KINEROS2 overland flow model and the OPUS soil water model under ponded conditions, verification will be based on a mass balance between the models in question.

The complexity and broad scope of KINEROS2-OPUS will preclude comprehensive validation using any single data set. Validation will proceed at different spatial scales depending on the availability of observed data relevant to each process or sub-process. For example, data to assess the conversion of rainfall to runoff is available over a large range of scales, from small experimental plots to gauged watersheds or river basins. Conversely, data suitable for evaluating the submodels for sediment, nitrogen, carbon, phosphorous, evapotranspiration, plant growth, and vertical soil water movement would be limited to the plot, field or lysimeter scale.

6.2 DotAGWA

The DotAGWA web application testing and validation has three components. The first testing component consists of verifying that the application produces expected output. Since the DotAGWA is dependent on the tools developed in AGWA2 then the application should produce the same output for a given set of inputs used in AGWA2. A complete testing suite will be developed just before a full-release of the application is made available to the user community. The test suite will consist of developing multiple inputs that represent how end-users may create for the application. These inputs will be run through the current version of AGWA2 (desktop). The outputs from these will be stored. Next the same inputs will be applied to DotAGWA and outputs will be stored.

Finally, the two different output sets will be compared to observe differences between them and verify the application is processing data as expected.

The second component involves application unit testing. This testing is currently being used in the application development. Unit testing involves identifying functional components of the application and then defining, developing, and running unique tests that try to "break" the components as well as verifying that the components produce expected behavior and/or output. Unit testing has been implemented using an Open Source programming tool called Nunit (http://www.nunit.org/). Nunit is a programming tool that can be connected to the Microsoft Visual Studio Integrated Development Environment (IDE) and used to programmatically build and run unit tests against DotAGWA application components.

The third testing component deals with the application data sets. Because DotAGWA is an Internet application based on the AGWA2 desktop application, it uses the same base datasets that have been used with AGWA since its inception (Hernandez et al., 2002; Miller et al., 2007). These data sets consist of various databases, and spatial datasets that are periodically reviewed by their creators. When these data sets are modified by their creators then the application data set(s) are updated to reflect these modifications. Error checking on these datasets is primarily dependent on their creators QA/QC processes.

6.3 AGWA2

The update of AGWA2 to include the WEPPCAT Climate Assessment Tool will first be tested to ensure compatibility with the defined inputs. Given appropriate inputs, the formatting and expected output of the tool will be verified. A range of inputs including realistic, extreme, and missing values will also be tested to ensure that the tool is capable of handling a variety of inputs gracefully and properly. Finally, the outputs of the tool will be tested as inputs to the models to ensure the linkage is working.

The code testing for the inclusion of KINEROS2-OPUS in AGWA2 will show that the model will run successfully using input files parameterized by AGWA2. Tests will verify that KINEROS2-OPUS input files are written and formatted correctly and that the model output files are correctly imported back into AGWA2. Verification/validation of the integration will compare, where appropriate, the parameterization and results of KINEROS2-OPUS with KINEROS2. Verification/validation of the AGWA2 integration will also use datasets used in the validation of the KINEROS2-OPUS model.

The update of AGWA2 to include SWAT 2005 will include testing that demonstrates the model will run successfully using input files parameterized by AGWA2. Tests will verify that SWAT 2005 input files are written and formatted correctly and that model output files are correctly imported back into AGWA2. Verification/validation of the integration will compare inputs and outputs written by AGWA2 for SWAT 2005 with inputs and outputs written by AGWA2 for SWAT 2000.

7 Documentation

Manuals for both the KINEROS2-OPUS model and DotAGWA web-based interface will be available on our web pages http://www.tucson.ars.ag.gov/agwa/, and http://www.epa.gov/nerlesd1/land-sci/agwa. A report documenting in detail the verification of the coupled KINEROS2-OPUS model in AGWA2 will be delivered to EPA. In addition, peer-reviewed articles will be published reporting research carried out using both KINEROS2-OPUS and DotAGWA computer applications.

The procedures followed to ensure that AGWA2 conforms to the design objectives and specifications, and that it correctly performs the incorporated function were reported in the document entitled "Quality Assurance and Quality Control in the Development and Application of the Automated Geospatial Watershed Assessment (AGWA) Tool by Hernandez et al. 2002 (EPA/600/R-02/046 and ARS/137460). A copy of the report is available for download at http://www.epa.gov/nerlesd1/land-sci/agwa/info.htm#qa, and http://www.tucson.ars.ag.gov/agwa

8 Task and Delivery Schedule

Tasks described in this document were defined in the Interagency Agreement with USDA-ARS (DW12922094-01-0 Forecasting Water Quality and Quantity Hazards Using Spatially Distributed Watershed Models and Biophysical Data). The schedule for their completion is defined in table 2.

Table 2. Primary IAG tasks involving QA and their associated completion schedule.

Task	Completion Date
Integration of Opus model features into new KINEROS2 model framework	3rd Quarter, FY07
Conduct verification of integrated KINER-OPUS model and its implementation in the AGWA 2.0 interface and document in report	4th Quarter, FY08
Enable additional AGWA 2.0 functionality in the DotAGWA web interface	3rd Quarter, FY07
Update AGWA 2.0 to include the WEPPCAT Climate Assessment Tool	4th Quarter, FY07
Create classified SWReGap land-cover data for the Mexican portions of the San Pedro and Santa Cruz basins.	1st Quarter, FY08
Update AGWA to enable the use of SWAT 2005 (an updated version), and verify	4th Quarter, FY07

References

American Society of Civil Engineers, T. C., 1999. GIS modules and distributed models of the watershed. American Society of Civil Engineers, Reston, Virginia. Pp.120p.

Cate, A. J., D. J. Semmens, I. S. Burns, D. C. Goodrich, and W. G. Kepner, 2005. AGWA design documentation: migrating to ArcGIS TM and the Internet, USDA/Agricultural Research Service, Southwest Watershed Research Center, Tucson, AZ, Report No. ARS/181027; U. S. Environmental Protection Agency, Landscape Ecology Branch, Las Vegas, NV, EPA, Office of Research and Development, Washington, DC, 20460, EPA/600/R-05/056

Fowler, H. J., and C. G. Kilsby, 2007. Using regional climate model data to simulate historical and future river flows in northwest England. Climatic Change 80:337-367.

Hernandez, M., Scott Miller, Darius Semmens, David C. Goodrich, W. P. Miller, and William G. Kepner. 2002. Quality Assurance and Quality Control in the Development and Application of the Automated Geospatial Watershed Assessment (AGWA) Tool. EPA/600/R-02/046 and ARS/137460.

Karl, T. R., R. W. Knight, and N. Plummer, 1995. Trends in high-frequency variability in the twentieth-century. Nature 377:217-220.

Jones, J. L., J. M. Fulford, and F. D. Voss, 2002. Near-real-time and internet-based delivery of forecast-flood inundation maps using two-dimensional hydraulic modeling: a pilot study of the Snoqualmie river, Washington. U.S. Geological Survey, Water Resources Investigation Report 02-4251.

Kepner, W. G., D. J. Semmens, S. D. Basset, D. A. Mouat, and D. C. Goodrich, 2004. Scenario analysis for the San Pedro River, analyzing hydrological consequences for a future environment. Environmental Modeling and Assessment, 94:115-127.

Kepner, W. G., M. Hernandez, D. J. Semmens, and D.C. Goodrich, 2007. The use of scenario analysis to assess future landscape change on watershed condition in the Pacific Northwest (USA). In: K. B. Jones, W. G. Kepner, K. Krauze, B. Li, I. Petrosillio (eds.) Use of landscape sciences for the assessment of environmental security. Springer Publisher. Book in press

Kundzewicz, Z. W. and A. W. Kaczmarek, 2000. Coping with hydrological extremes. Water International 25(1):66-75.

Leavesley, G. H., 1994. Modeling the effects of climate change on water resources – A review. Climatic Change 28:159-177.

Liu, Yuqiong, M. Mahmoud , H. Hartmann,S. Stewart, T. Wagener, D. J. Semmens, R. Stewart, H. Gupta, D. Dominguez, D. Hulse, R. Letcher, B. Rashleigh, C. Smith, R.

Street, J. Ticehurst, M. Twery, H. van Delden, R. Waldick, D. White, and L. Winter, (In review). Formal scenario development for environmental impact assessment studies. Submited to: Environmental Modeling and Software.

Miller, S. N., D. J. Semmens, D. C. Goodrich, M. Hernandez, R. C. Miller, W. G. Kepner, D. P. Guertin, 2007. The automated geospatial watershed assessment tool. Environmental Modelling and Software, Vol (22), pp. 365-377.

Nicks, A. D., J. L. Lane, and G. A. Gander, 1995. Chapter 2. Weather Generator. USDA-Water Erosion Prediction Project: Hillslope Profile and Watershed Model Documentation, NSERL Report No. 10; D. C. Flanagan and M. A. Nearing, Eds. NSERL West Lafayette, IN, USDA-ARS National Soil Erosion Research Laboratory, 2.1-2.22.

Ogden, F. L. , J. Garbrecht, and P. A. DeBarry, and L. E. Johnson, 2001. GIS and distributed watershed models II: Modules, interfaces and models. Journal of Hydrologic Engineering, 6(6): 515-523.

Semmens, D. J., M. Hernandez, D. C. Goodrich, and W. G. Kepner, 2006. Hydrologic model uncertainty associated with simulating future land-cover/use scenarios: a retrospective analysis, Second Interagency Conference on Research in Watersheds Proceedings, May 16-18, 2006, Coweeta Hydrologic Research Station, NC.

Sivapalan, M., K. Takeuchi, S. W. Franks, V. K. Gupta, H. Karambiri, V. Lakshmi, X. Liang, J. J. McDonell, E. M. Mendiondo, P. E. O'Conell, T. Oki, J. W. Pomeroy, D. Schertzer, S. Uhlenbrook, E. Zehe, 2003. IAHS decade on predictions in ungauged basins (PUB), 2003-2012: shaping an exciting future for the hydrological sciences. Hydrological Sciences Journal 48(6):857-880.

Smith, R. E., 1992a. OPUS: An integrated simulation model for transport of non-point-source pollutants at field scale, Vol. I, USDA, Washington, DC, Documentation, USDA ARS-98.

Smith, R. E., 1992b. OPUS: An integrated simulation model for transport of non-point-source pollutants at field scale, Vol. II, USDA, Washington, DC, User Manual, USDA ARS-98.

Smith, R. E., D. C. Goodrich, D. A. Woolhiser, and C. L. Unkrich, 1995. KINEROS: A kinematic runoff and erosion model. pages 697-732 in V.P. Singh, editor. Computer Models of Watershed Hydrology. Water Resources Publications, Highlands Ranch, CO.

Smith, R. E., and J.-Y. Parlange. 1978. A parameter-efficient hydrologic infiltration model. Water Resources Research, 14(33):533-538.

Taylor, J. K., 1985. What is quality assurance? Pages 5-11in J. K. Taylor and T. W. Stanley, editors. Quality Assurance for Environmental Measurements. American Society for Testing and Materials, Special Technical Publication No. 867, Philadelphia, Pennsylvania.

Tsonis, A. A., 1996. Widespread increases in low-frequency variability of precipitation over the last century. Nature 382:700-702.

Tsonis, A. A., 2004. Is global warming injecting randomness into the climate system? EOS Transaction American Geophysics Union, 85(38):361-364.

U. S. Environmental Protection Agency, 2005. EPA National Geospatial Data Policy; CIO Policy Transmittal 05-022, Classification No. 2121, http://www.epa.gov/glnpo/fund/ngdp.pdf.

U. S. Environmental Protection Agency, 2001. Better Assessment Science Integrating Point and Nonpoint Sources (BASINS). Version 3.0 User's Manual. U. S. Environmental Protection Agency, EPA-823-C-01-001. Washington, D.C.

U. S. Environmental Protection Agency, 1991. Quality assurance guidelines for modeling, Development and Application Projects, Environmental Research Laboratory, Duluth, Minnesota.

U. S. Environmental Protection Agency (1997). Guiding principles for Monte Carlo analysis. EPA/630/R-97/001, U. S. Environmental Protection Agency, Washington, DC.

Van der Heijde, P. K. M., 1987. Quality assurance in computer simulations of groundwater contamination. Environmental Software, 2(1):19-28.